

BUILDING DESIGN FOR HOMELAND SECURITY

Unit VI

Explosive Blast



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Unit Objectives

Explain the basic physics involved during an explosive blast event, whether by terrorism or technological accident.

Explain building damage and personnel injury resulting from the blast effects upon a building.

Perform an initial prediction of blast loading and effects based upon incident pressure.



Unit VI: Explosive Blast

Units I-V discussed Assessments - Risk

Units VI and VII explain Blast and CBR Weapons and effects

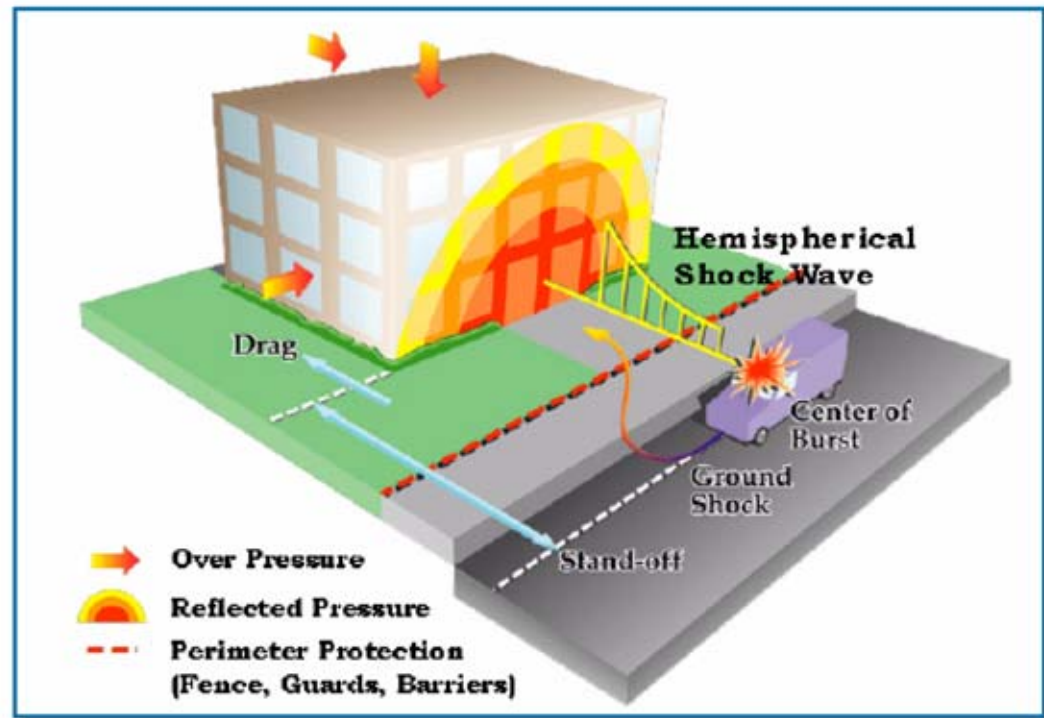
Units VIII and IX demonstrate techniques for site layout and building design to counter or mitigate manmade threats



Blast Loading Factors

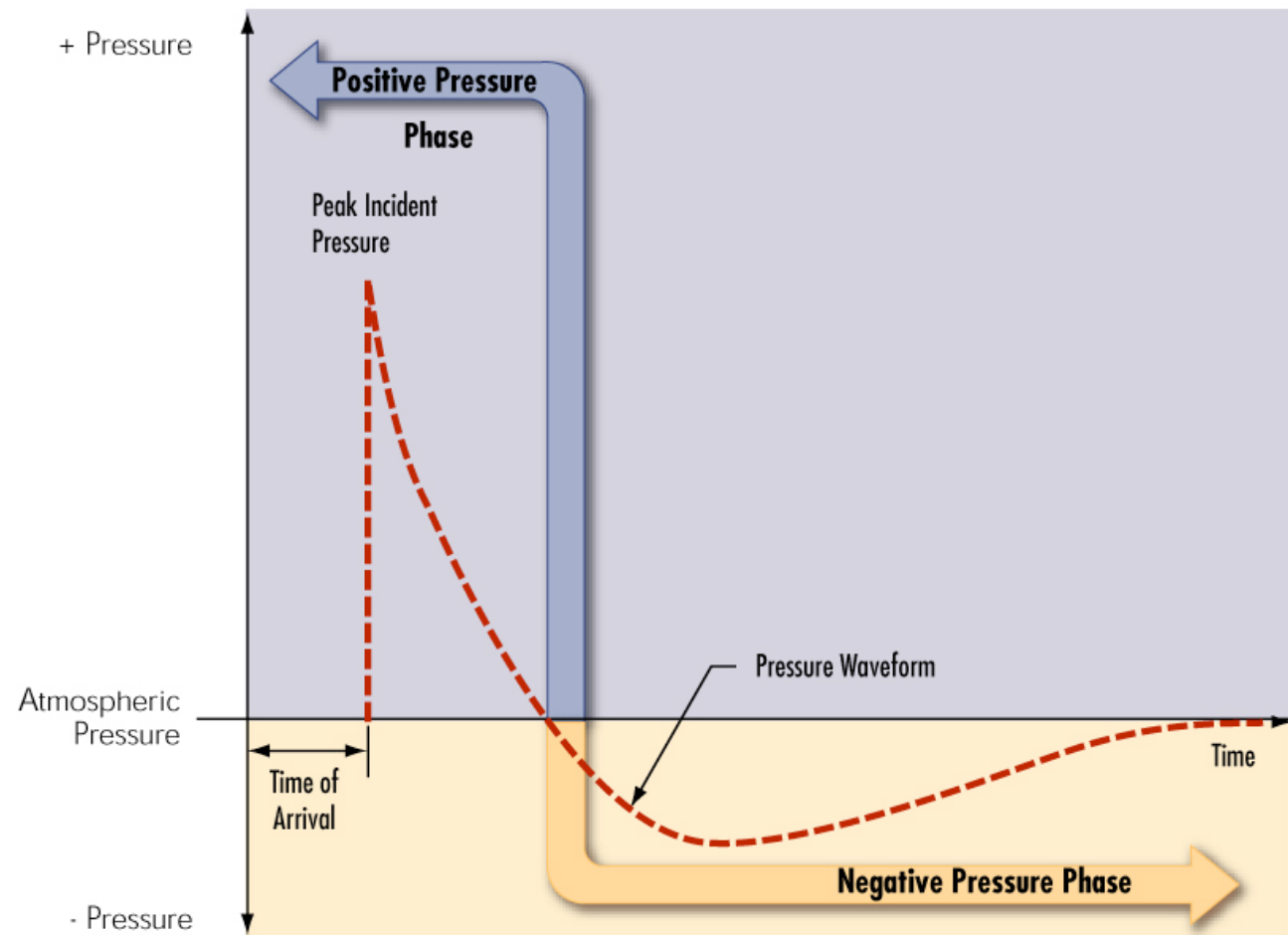
Explosive properties

- Type
- Energy output (TNT equivalency)
- Quantity



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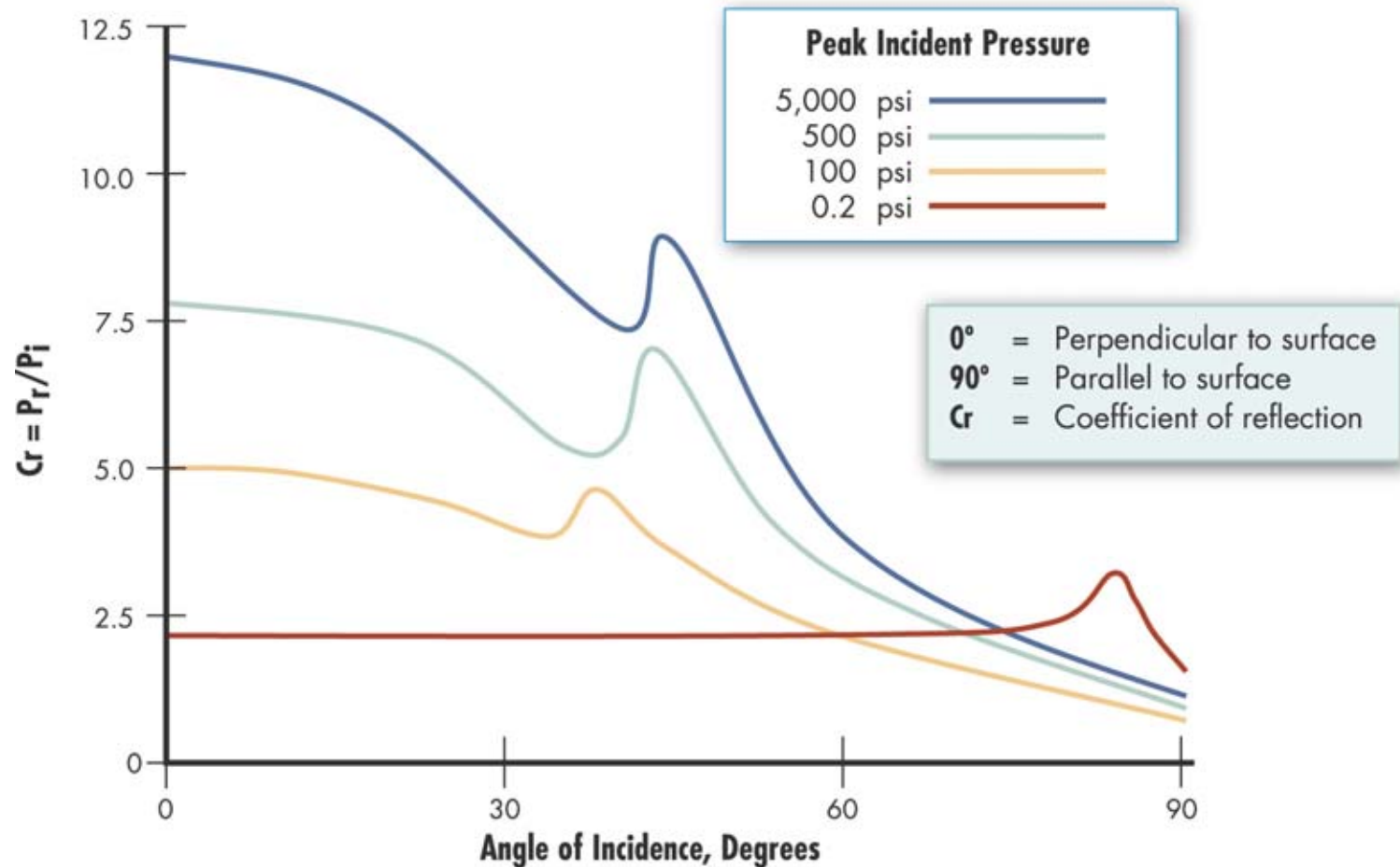
Typical Incident Pressure Waveform



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Figure 4-3: Typical Impulse Waveform, page 4-4

Reflected Pressure/Angle of Incidence

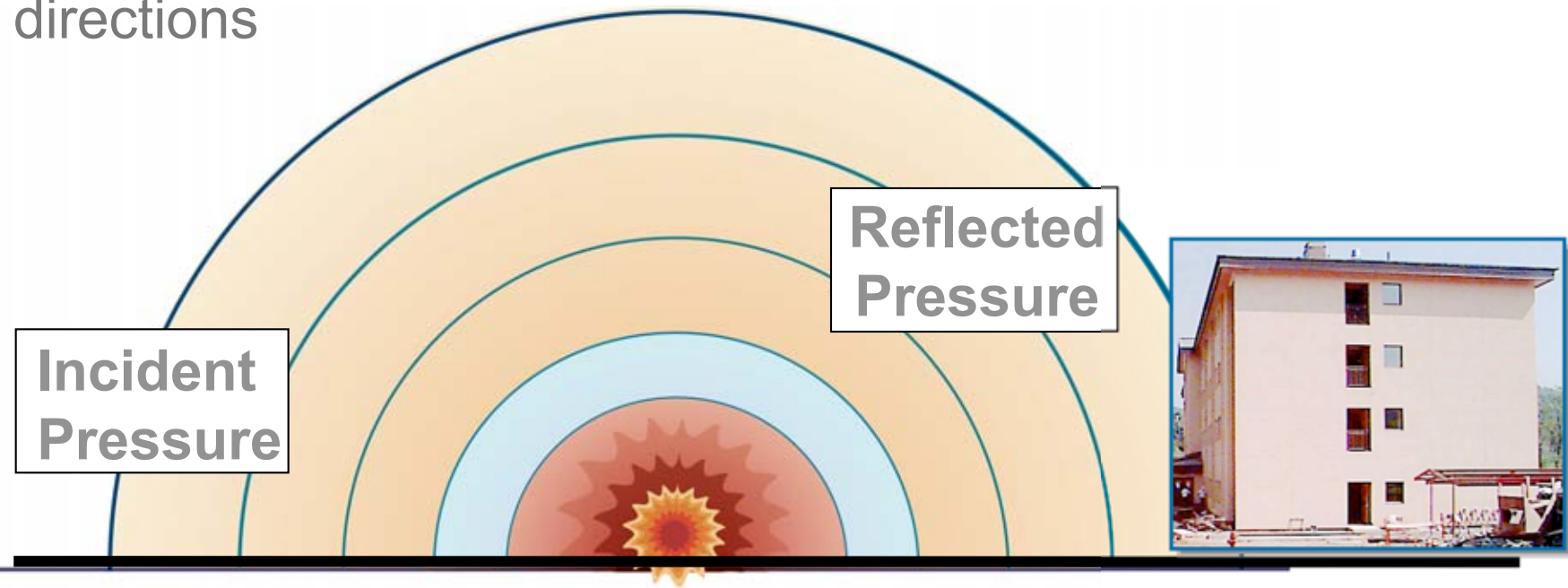


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Figure 4-2: Reflected Pressure Coefficient vs. Angle of Incidence, page 4-3

Incident and Reflected Pressure

Blast energy lost at rate of volume increase in X, Y, and Z directions



Equivalent pressure occurs at Scaled Distance =
Distance / (Net Explosive Weight, TNT equivalent)^{1/3}



Typical Blast Impulse Waveform

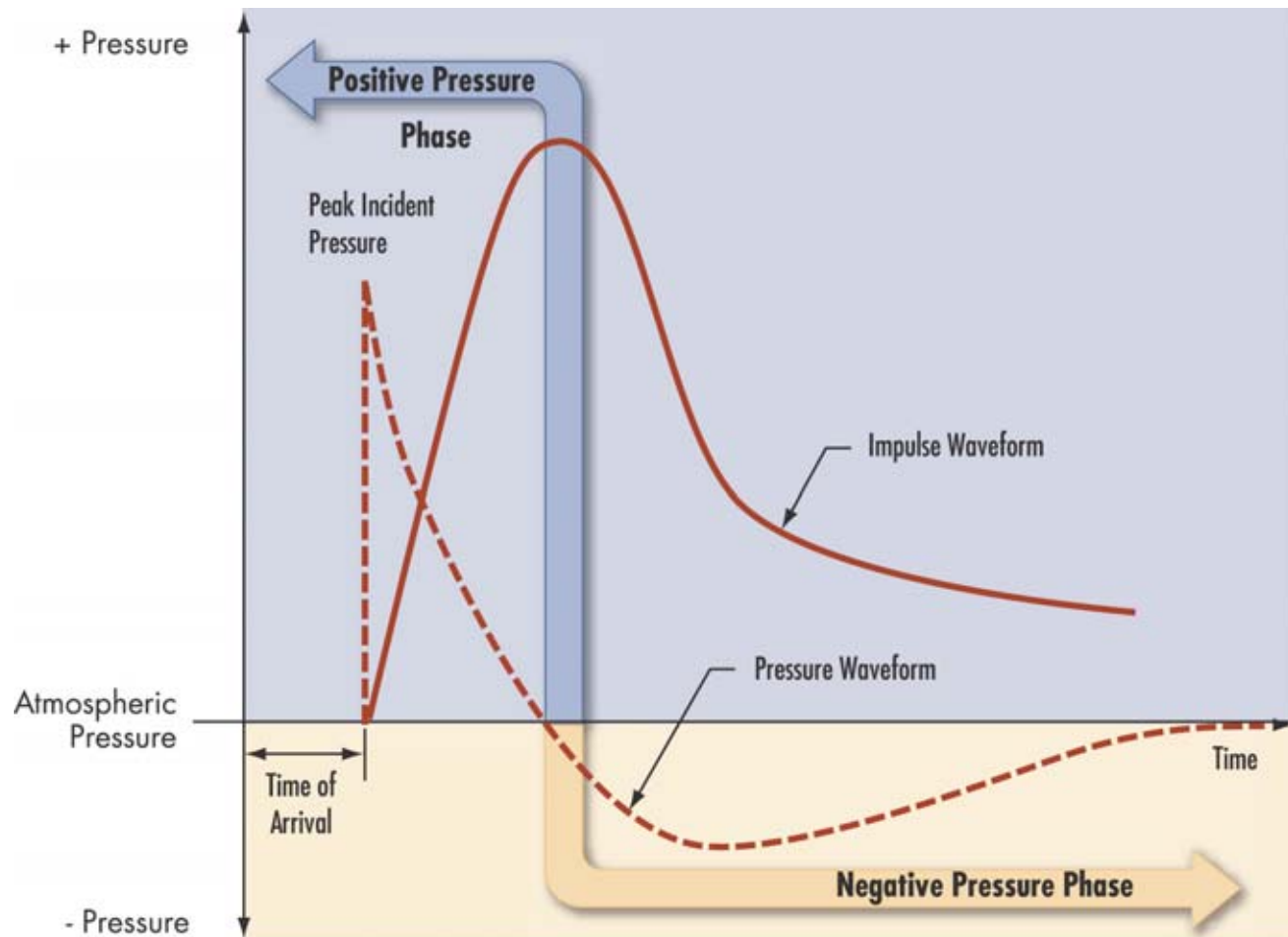


Figure 4-3: Typical Impulse Waveform, page 4-4



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Blast Loading Factors

Location of explosive relative to structure

- Stand-off distance
- Reflections and reflection angle
 - Ground
 - Buildings
- Identify worst case



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Blast Compared to Natural Hazards

Higher incident pressures and relatively low impulse

- High explosive (C-4)
- Low-order explosive (ANFO)
- Aircraft or vehicle crash combines kinetic energy (velocity, mass), explosive loads, and fuel/fire
- 200 mph hurricane generates only 0.8 psi, but with very large impulse



Blast Compared to Natural Hazards

Direct airblast causes more localized damage

- Component breakage
- Penetration and shear
- Building's other side farther away
- Reflections can increase damage on any side

Greater mass historically used for blast protection

- Greater mass usually detrimental during earthquake due to resonance



Factors Contributing to Building Damage

First approximations based upon:

- Quantity of explosive
- Stand-off distance between building and explosive
- Assumptions about building characteristics



Types of Building Damage

Direct Air Blast

- Component failure
- Additional damage after breaching

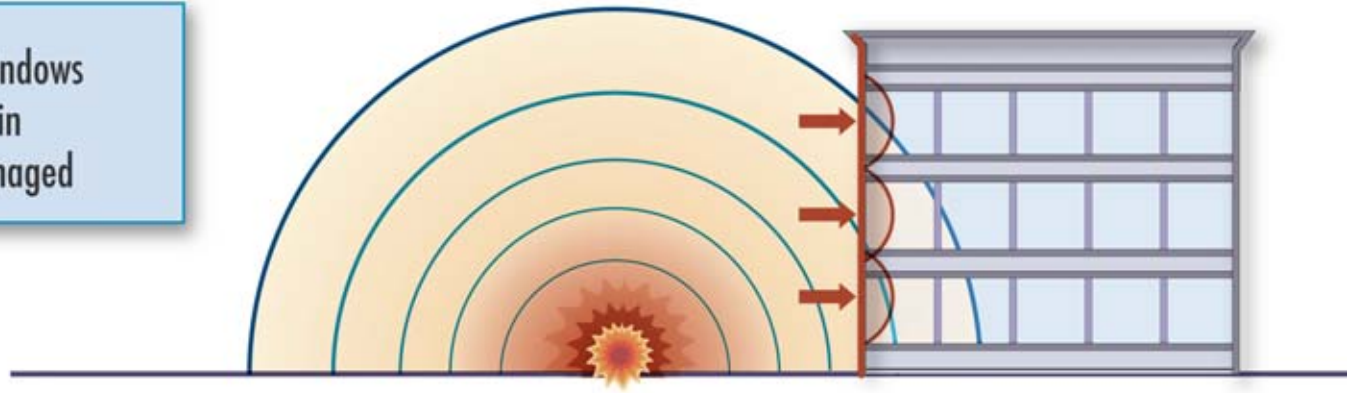
Collapse

- Localized
- Progressive



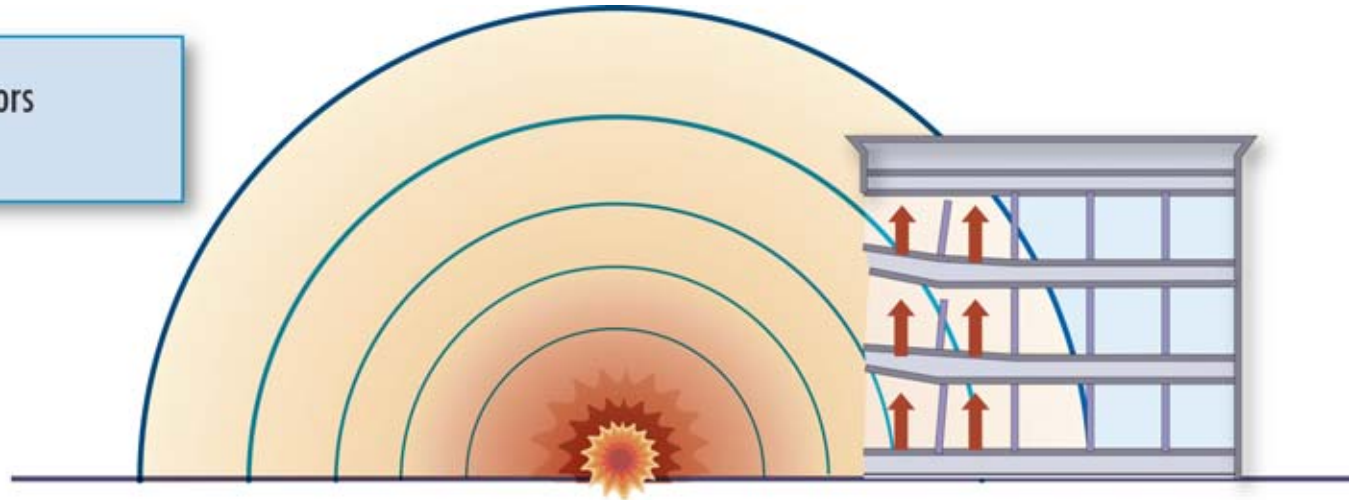
Blast Pressure Effects

1. Blast wave breaks windows
Exterior walls blown in
Columns may be damaged

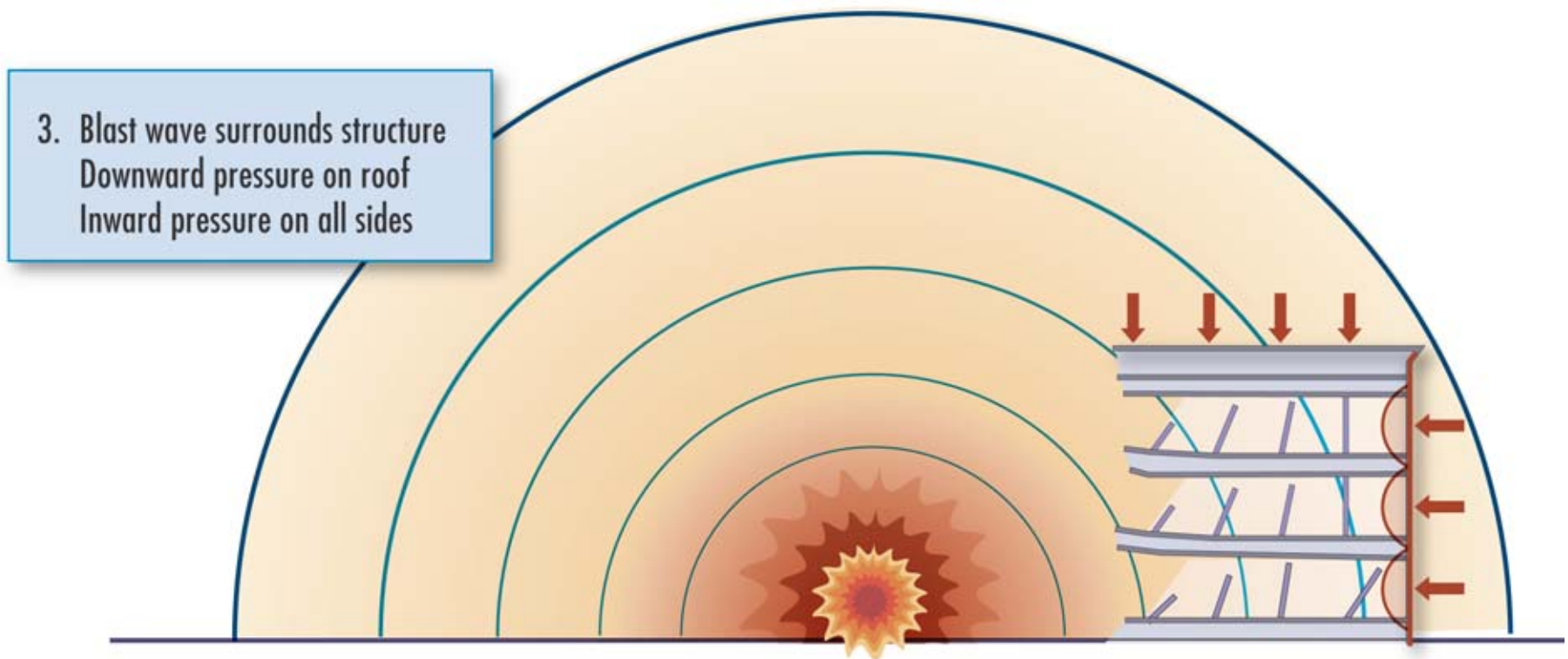


Blast Pressure Effects

2. Blast wave forces floors upward



Blast Pressure Effects



Causes of Blast Injuries (1)

Overpressure

- Eardrum rupture
- Lung collapse/failure

Blast Wave

- Blunt trauma, lacerations, and impalement



Causes of Blast Injuries (2)

Fragmentation

Bomb or vehicle

Street furniture or jersey barriers

Building component failure

- Glass – predominant
- Walls
- Floors



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Murrah Federal Building, Oklahoma City



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Murrah Federal Building, Oklahoma City

The majority of deaths were due to the collapsing structure

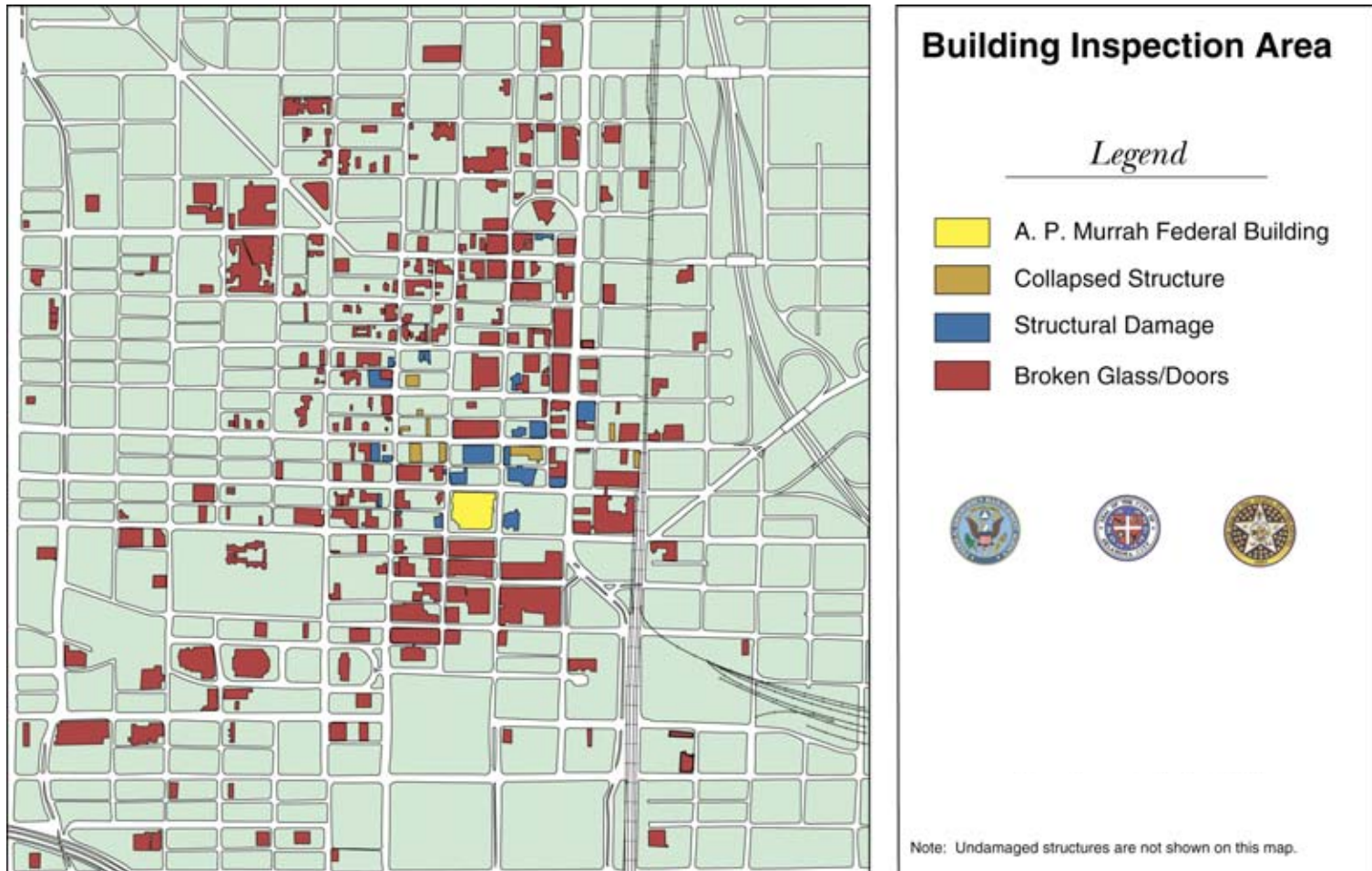


Journal of American Medical Association, August 7, 1996.



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Murrah Federal Building, Oklahoma City



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Levels of Protection (1)

CONVENTIONAL CONSTRUCTION

INCIDENT OVERPRESSURE

Level of Protection	Potential Structural Damage	Potential Door and Glazing Hazards	Potential Injury
Below AT standards	Severely damaged. Frame collapse/massive destruction. Little left standing.	Doors and windows fail and result in lethal hazards. GSA 5	Majority of personnel suffer fatalities.
Very Low psi = 3.5	Heavily damaged - onset of structural collapse. Major deformation of primary and secondary structural members, but progressive collapse is unlikely. Collapse of non-structural elements.	Glazing will break and is likely to be propelled into the building, resulting in serious glazing fragment injuries, but fragments will be reduced. Doors may be propelled into rooms, presenting serious hazards. GSA 4	Majority of personnel suffer serious injuries. There are likely to be a limited number (10 percent to 25 percent) of fatalities.
Low psi = 2.3	Damage – unrepairable. Major deformation of non-structural elements and secondary structural members and minor deformation of primary structural members, but progressive collapse is unlikely.	Glazing will break, but fall within 1 meter of the wall or otherwise not present a significant fragment hazard. Doors may fail, but they will rebound out of their frames, presenting minimal hazards. GSA 3a	Majority of personnel suffer significant injuries. There may be a few (<10 percent) fatalities.



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Taken from Table 4-1, DoD Minimum Antiterrorism Standards for New Buildings, page 4-9

Levels of Protection (2)

CONVENTIONAL CONSTRUCTION

INCIDENT OVERPRESSURE

Level of Protection	Potential Structural Damage	Potential Door and Glazing Hazards	Potential Injury
Medium psi = 1.8	Damaged – repairable. Minor deformations of non-structural elements and secondary structural members and no permanent deformation in primary structural members.	Glazing will break, but will remain in the window frame. Doors will stay in frames, but will not be reusable. GSA 2	Some minor injuries, but fatalities are unlikely.
High psi = 1.1	Superficially damaged. No permanent deformation of primary and secondary structural members or non-structural elements.	Glazing will not break. Doors will be reusable. GSA 1	Only superficial injuries are likely.



Taken from Table 4-1, DoD Minimum Antiterrorism Standards for New Buildings, page 4-9

Nominal Range-to-Effect Chart

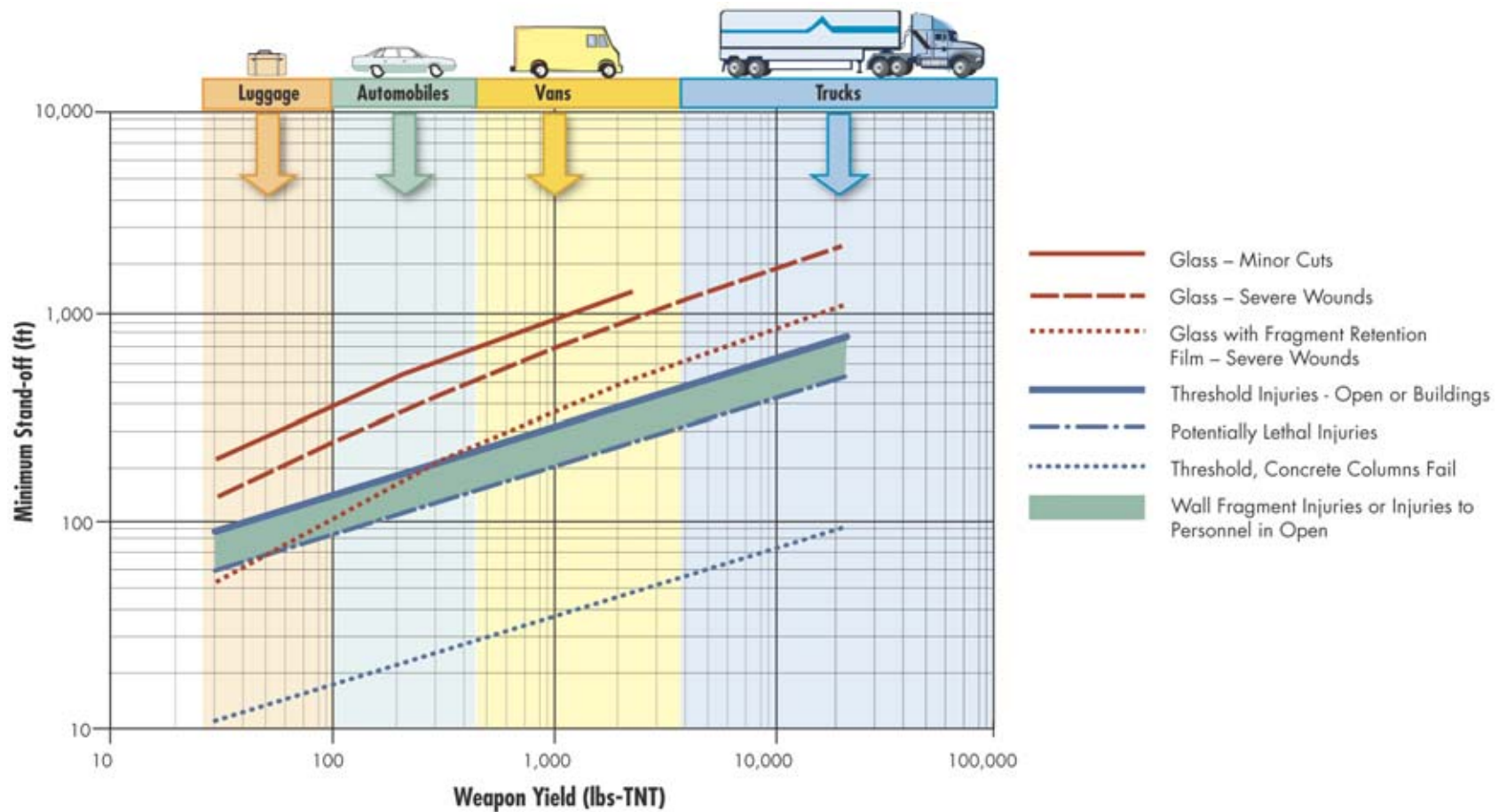


Figure 4-5: Explosive Environments – Blast Range to Effects, page 4-11, FEMA 426



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Comparison of Stand-off



Murrah Federal Building

YIELD (≈TNT Equiv.) 4,000 lb.
Reflected PRESSURE 9,600 psi.
Stand-off 15 feet

166 killed



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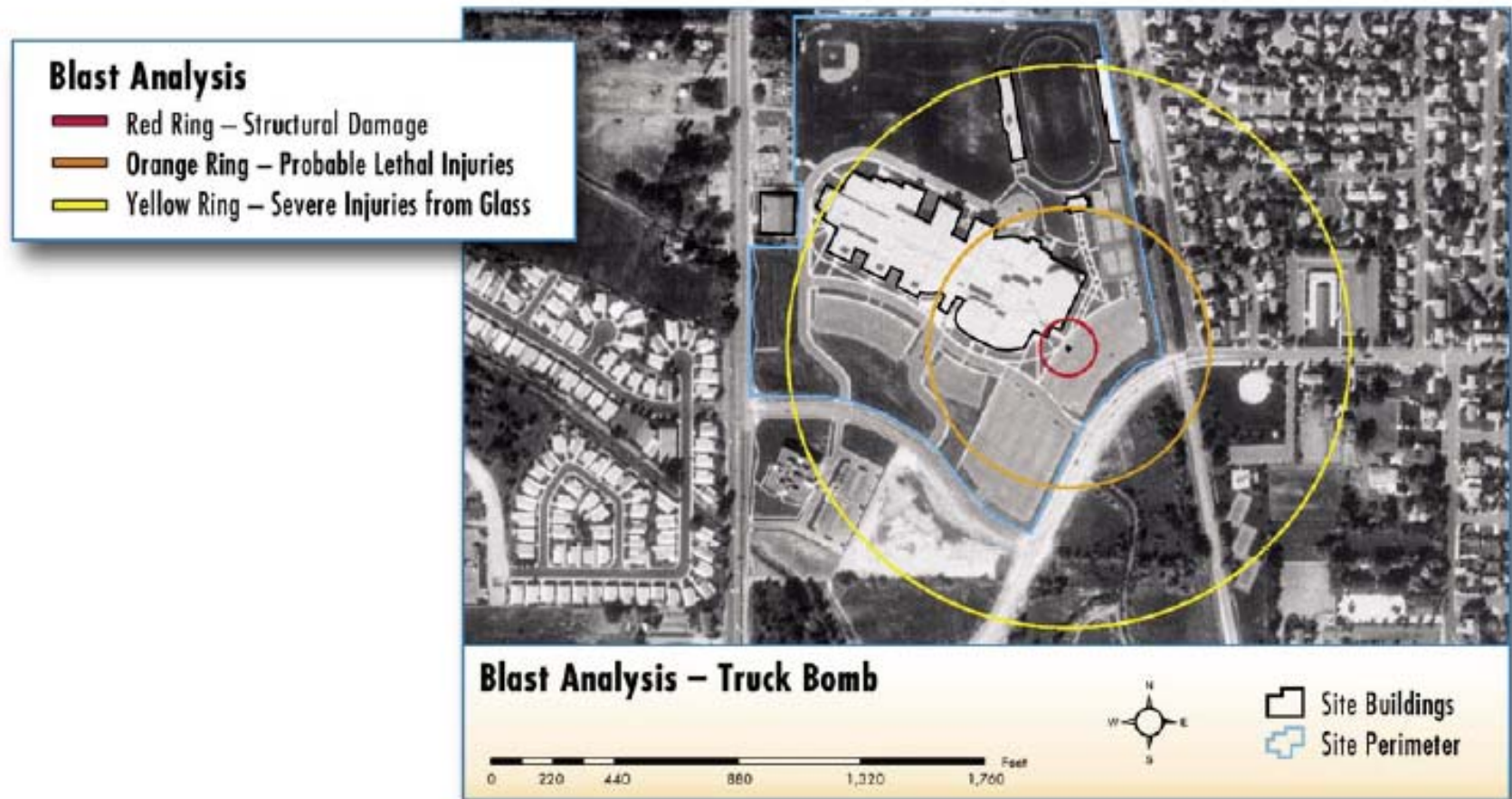


Khobar Towers

YIELD (≈TNT Equiv.) 20,000 lb.
Reflected PRESSURE 800 psi.
Stand-off 80 feet

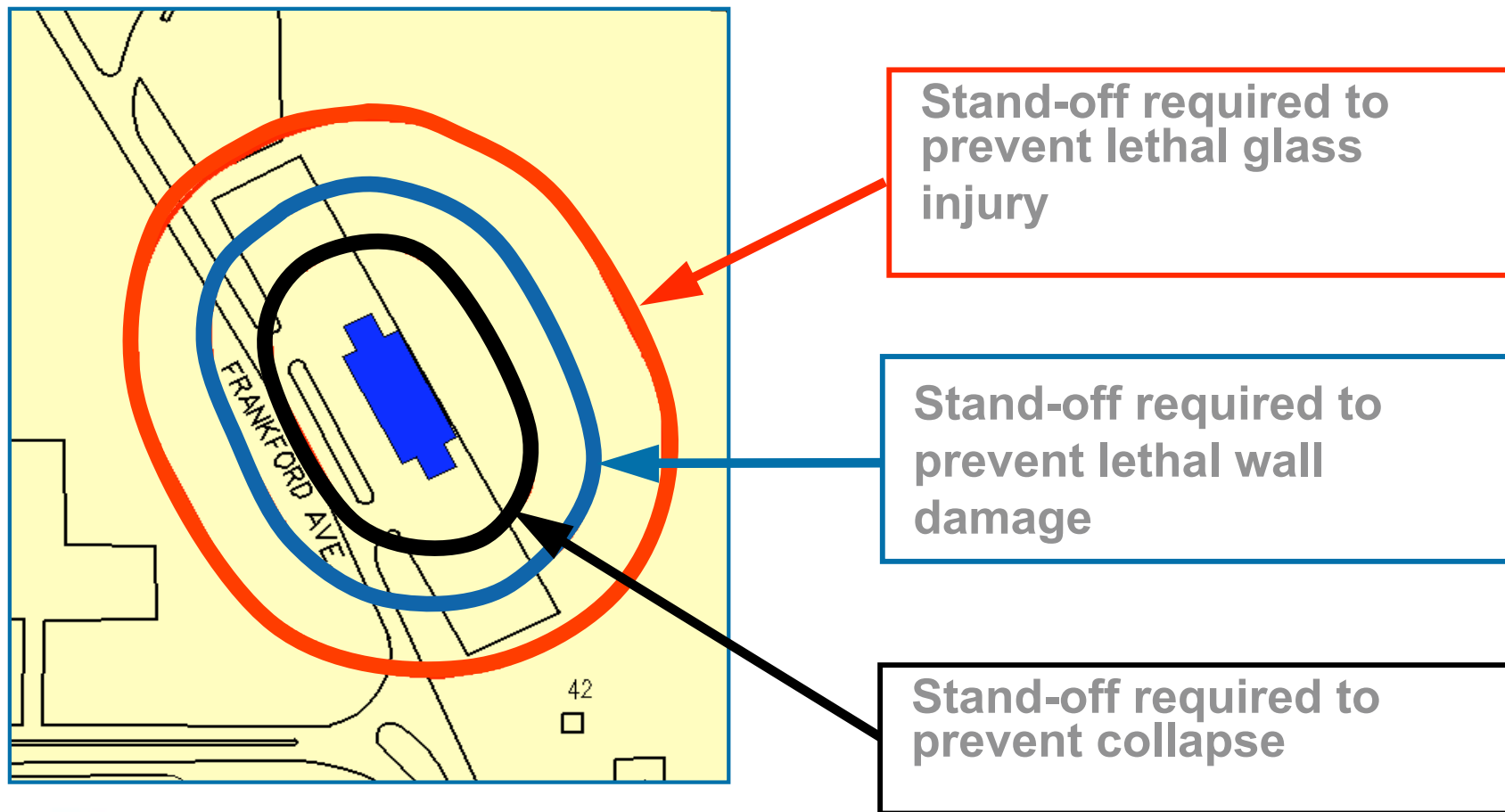
19 killed

Vulnerability Radii



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Iso-Damage Contours



Cost Versus Stand-off

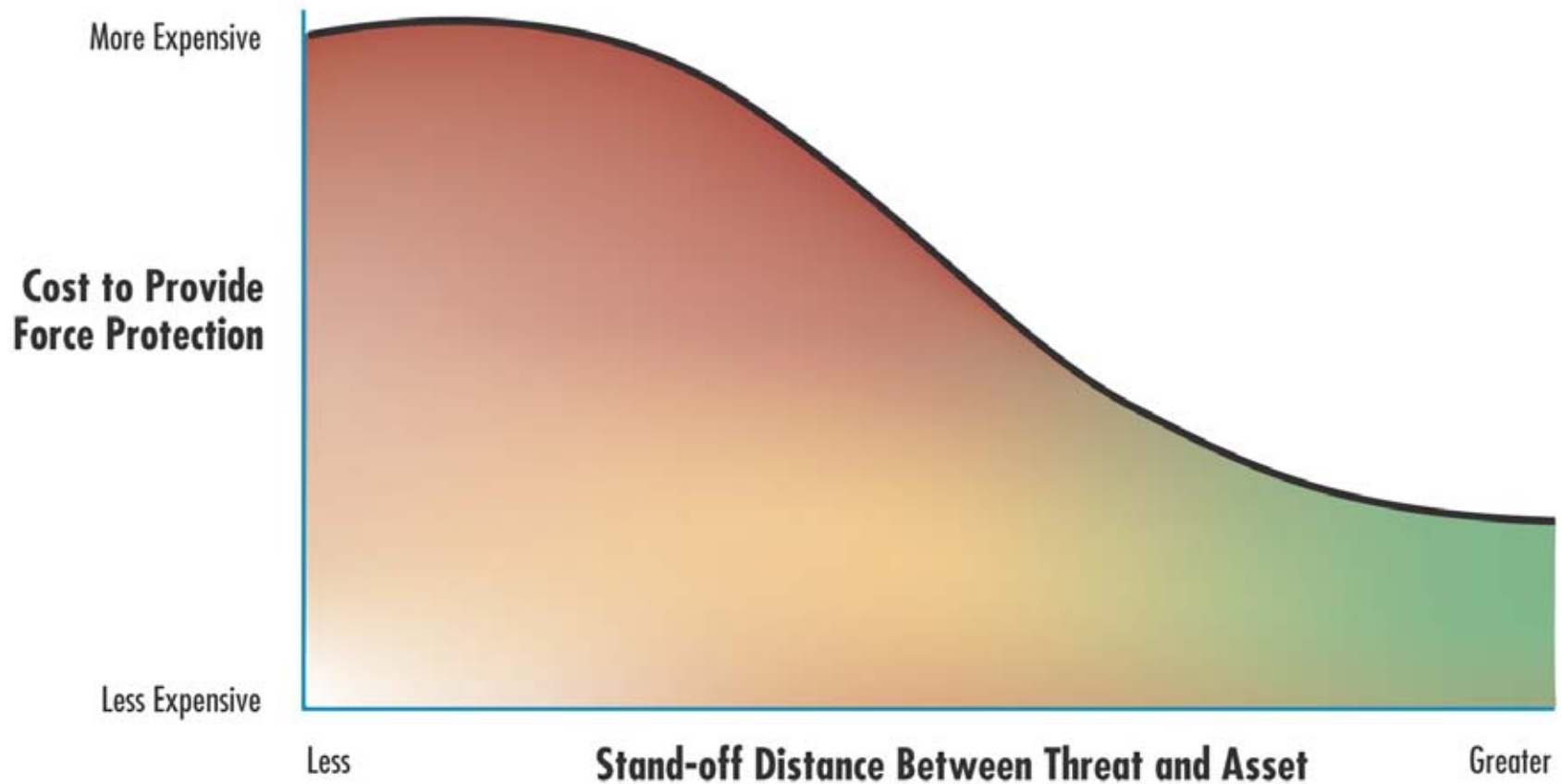


Figure 4-8: Relation of Cost to Stand-off Distance,
page 4-13

Blast Load Predictions

Incident and reflected pressure and impulse

- Software
 - Computational Fluid Dynamics
 - ATBLAST (GSA)
 - CONWEP (US Army)
- Tables and charts of predetermined values



Pressure versus Distance

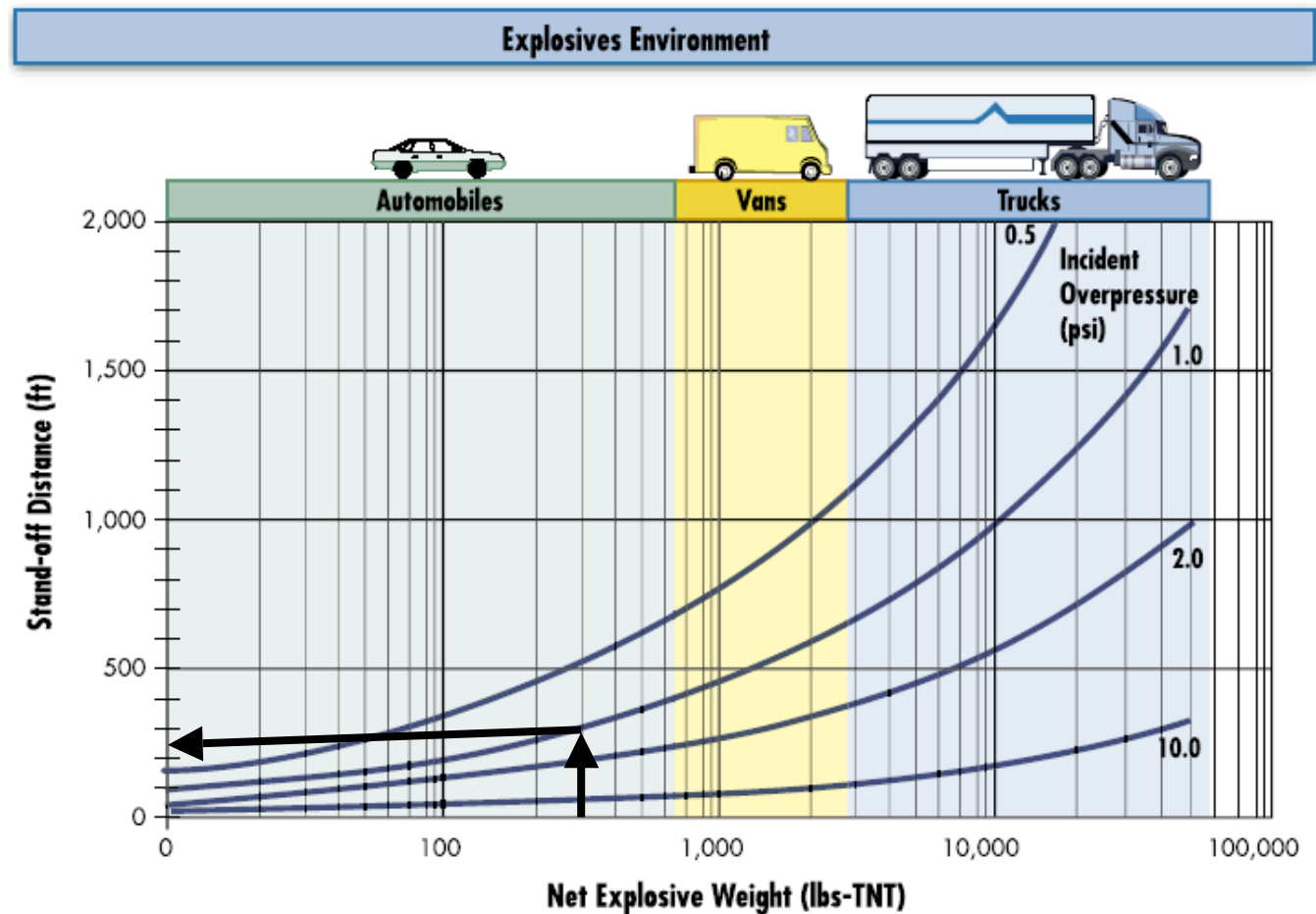


Figure 4-10: Incident Overpressure Measured in Pounds Per Sq. Inch, as a Function of Stand-Off Distance and Net Explosive Weight, page 4-17, FEMA 426



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Blast Damage Estimates (1)

Assumptions - pressure and material

- Software - SDOF
 - AT Planner (U.S. Army)
 - BEEM (TSWG)
 - BlastFX (FAA)
- Software - FEM
- Tables and charts of predetermined values



Blast Damage Estimates (2)

Damage	Incident Pressure (psi)
Typical window glass breakage (1)	0.15 – 0.22
Minor damage to some buildings (1)	0.5 – 1.1
Panels of sheet metal buckled (1)	1.1 – 1.8
Failure of unreinforced concrete blocks walls (1)	1.8 – 2.9
Collapse of wood frame buildings (2)	Over 5.0
Serious damage to steel framed buildings (1)	4 – 7
Severe damage to reinforced concrete structures (1)	6 – 9
Probable total destruction of most buildings (1)	10 – 12

(1) "Explosive Shocks in Air" Kinney and Grahm, 1985

(2) "Facility Damage and Personnel Injury from Explosive Blast" Montgomery and Ward, 1993; and "The Effects of Nuclear Weapons, 3rd Edition", Glasstone and Dolan, 1977

Level of Protection	Incident Pressure (psi)
High	1.2
Medium	1.9
Low	2.3
Very Low	3.5
Below AT Standards	> 3.5



Summary

Explosive blast physics

Blast damage to buildings

Injury to personnel

Prediction of loading, damage, and injury

- Range-to-effect chart
- Incident pressure chart



Unit VI Case Study Activity

Explosives Environment, Stand-off Distance and the Effects of Blast

Background

Purpose of activity: check on learning about explosive blast

Requirements

Refer to FEMA 426 and answer worksheet questions on explosive blast

